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APPLICATION OF NON-LINEAR OPTIMIZATION TO MULTIPURPOSE RESERVOIR SYSTEMS

by

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ABSTRACT

The aim of this research is to investigate the application of nonlinear programming techniques to multipurpose reservoir systems. A multipurpose multiple reservoir operation problem is a typical nonlinear large scale optimization problem. The currently applied techniques overcome the nonlinearity and dimensionality problems through simplification. To model the problem more closely, a successful trial is made in this study to apply the most efficient and suitable nonlinear programming techniques.

Although research in large scale nonlinear optimization has been in recent years a major subject of interest within the mathematical programming community, its application to reservoir systems is very limited. As a result of these activities software packages, as Lancelot, have been developed. Lancelot is a general purpose software package designed for solving large-scale nonlinear optimization problems. It uses Augmented Lagrangian and Conjugate Gradient methods. This software is used here successfully to solve an optimization problem formulated for a major river system, the Blue Nile in Sudan. The system has two in series reservoirs used for hydropower generation, maintaining minimum downstream flows and irrigation. For optimization, some features of the system have been modelled. These are sedimentation, evaporation, demand and flow. To represent the effect of sedimentation a model is fitted and verified. To include the effect of evaporation a model that estimates the total evaporation losses is fitted using Penman approach and verified using water balance. To cope with flow uncertainty the Blue Nile flow has been modelled. ARMA(1,1) has given the best fitting. Irrigation requirements have been estimated using Penman-Monteith approach. Efficiency of water use has been investigated and other possible demand scenarios resulting from efficient water use are obtained. The results of flow and demand modelling are used as direct input to the optimization model while sedimentation and evaporation models are incorporated in the model.

The objective of this model is to maximise power benefits on condition that certain irrigation and downstream requirements be met. To solve this problem a double precision version of Lancelot was installed in a hp-UNIX system. For the problem a

specification and a standard input format, SIF, files were written and put under the same directory with Lancelot to run the program. The problem was solved successfully in few minutes. The solution includes values for the objective function, decision variables (releases and storage volumes), penalty parameter, Lagrange multipliers and slack variables.

In reservoir operation, general operation rules are needed more than computed releases corresponding to specified flow sequences. To achieve this, the optimization model is solved repeatedly using different generated flow sequences. The optimum releases are then regressed linearly and nonlinearly on the important independent variables, flows and/or storage volumes, to derive operation rules. The derived rules have been tested successfully both statistically using R^2 criterion and simulation. To be easily used in practice the rules are presented in a graphical form.

The optimization output is affected by reservoir sedimentation. Therefore the developed optimization and sedimentation models have been linked to investigate sedimentation effect on optimization output along the course of reservoir operation. Results have shown that this approach can be used to investigate the effect of sedimentation on reservoir optimum output.

In, a multipurpose reservoir system, the optimization output for one purpose is affected by the efficiency of water use for other purposes. Therefore the effect of efficient water use in irrigation on power benefits is investigated. Results have shown an increment in benefits due to using irrigation water efficiently. This approach can be applied to systems where priority is given for one purpose over the others.